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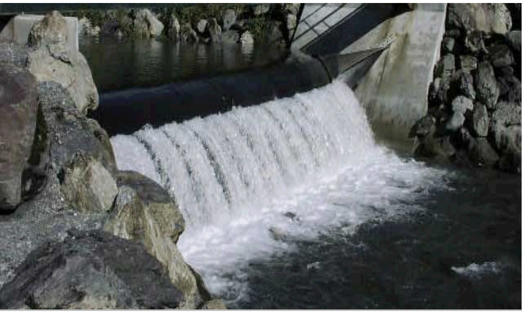

Cordova Energy Storage

07/11/2017

Benjamin Schenkman

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

SAND ______

Background

- Players
  - Cordova Electric Cooperative (CEC)
  - DoE/OE and Sandia National Labs (SNL)
  - Alaska Center for Energy and Power (ACEP)
- Issue
  - Expansion of fishing industry has exceeded the supply capability of the 7.25MW hydroelectric plants which supplemental power demand is met with diesel generation.
  - Supplemental power by diesel generation is only needed for minutes
  - Hydro units are run with a 500kW reserve which energy storage can free up and defer diesel generation

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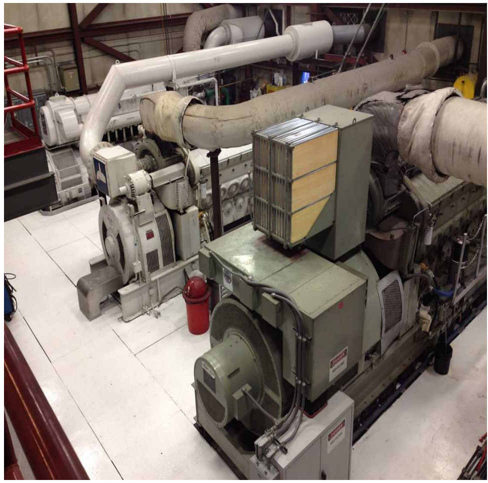
CEC Electric System Overview

- Member-owned COOP serving 2,000 customers with summer load peak of 8.4MW
- Generation Assets
  - Pump Creek: 2 hydro units, 3MW each
  - Humpback Creek: 3 hydro units, Total 1.25MW
  - Orca Power Plant: 5 diesel units, Total of 10.8MW
- Distribution system is underground
- SCADA system records over 200 channels of system data at 1 second intervals with over 10 years worth of data



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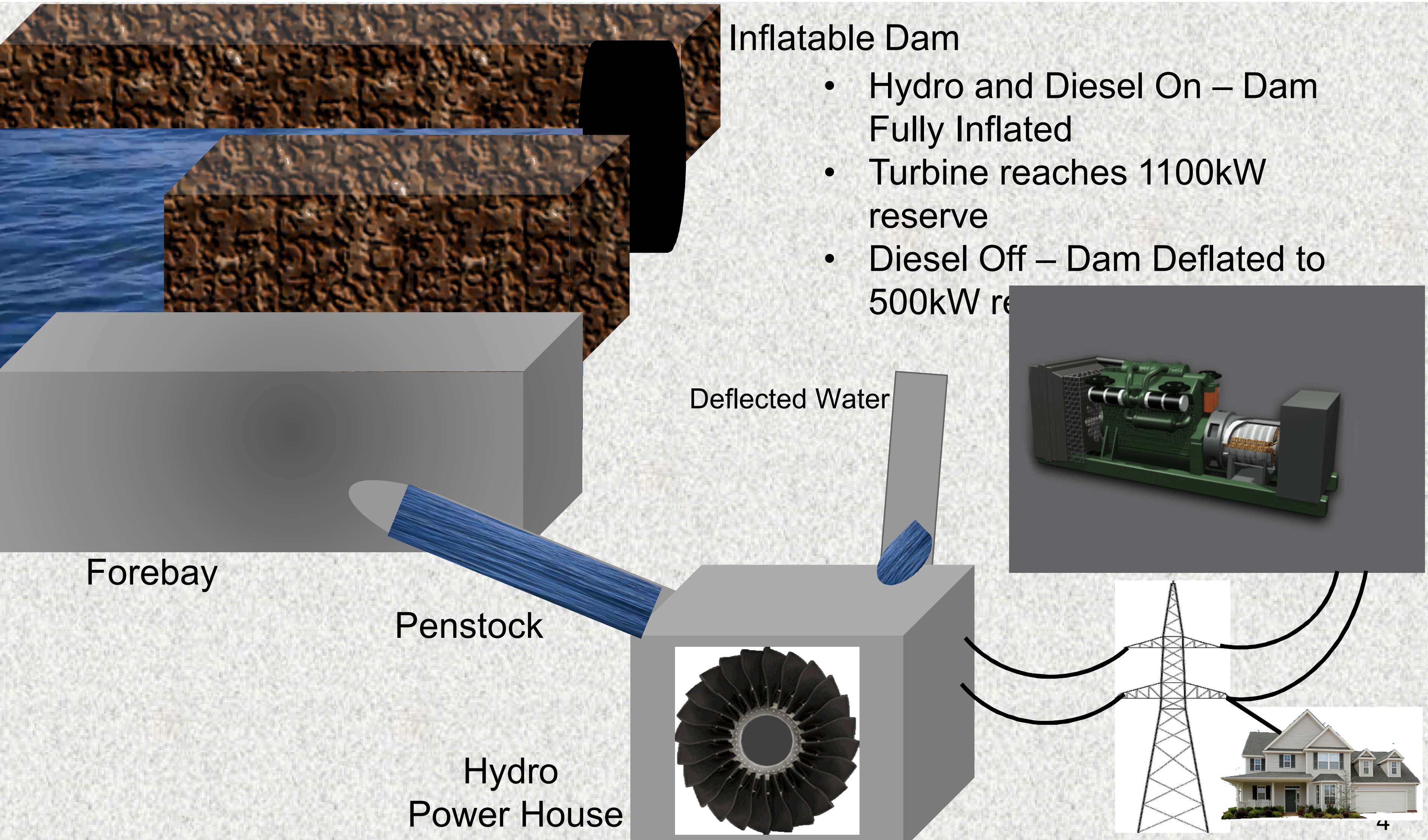
Diesel/Hydro Control

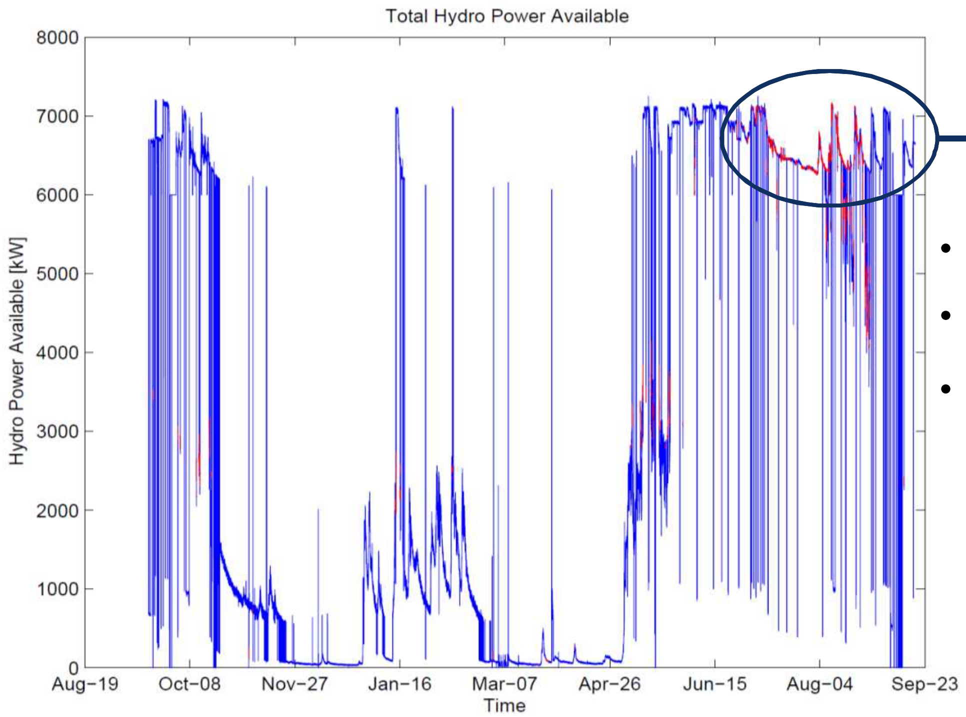
Inflatable Dam

- Hydro and Diesel On – Dam Fully Inflated
- Turbine reaches 1100kW reserve
- Diesel Off – Dam Deflated to 500kW re



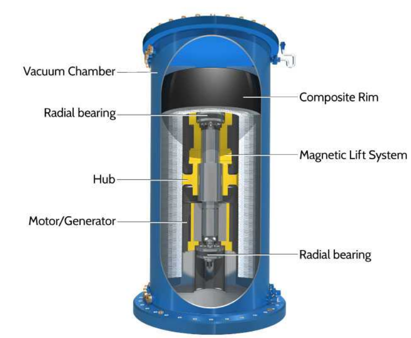
2014 Study Summary

- Determine if Diesel Deferral using Energy Storage is Feasible
  - Energy balance model of Cordova created by ACEP



Red is when 0kW < $P_{ah} - P_d$ < 500kW

- **Energy Storage Size ~500kW/100kWh**
- **Total displaceable diesel hours: 185.4589h**
- **Savings based on $0.35/kWh is $42,498/year**



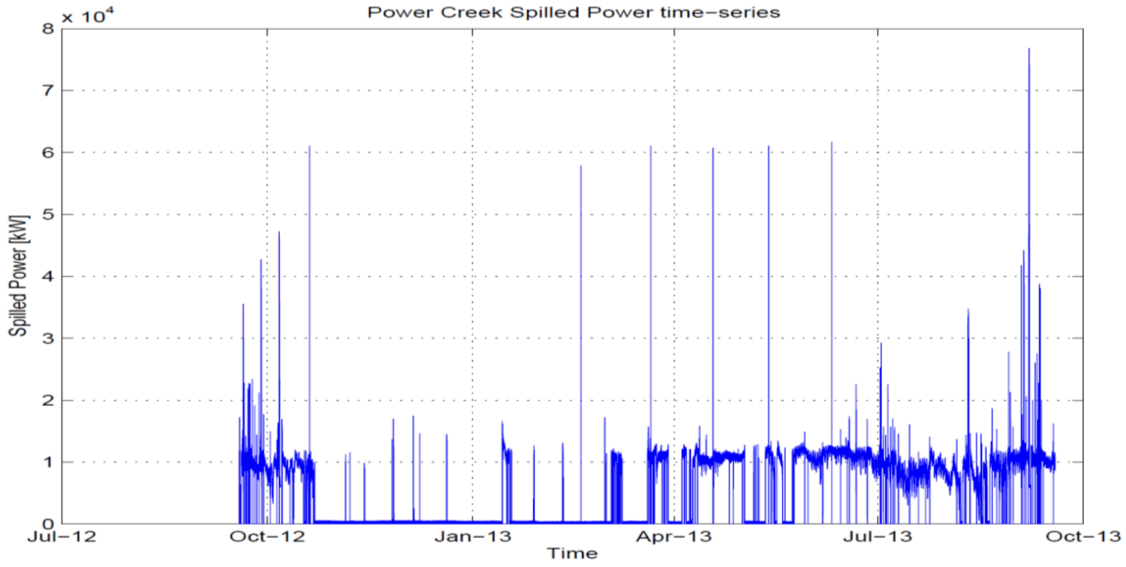
www.energystorageexchange.org

2014 Summary/Conclusions

- Power class energy storage system will not have significant economic benefit for CEC

- Recovering water spilled during times when load demand is below the hydropower capacity may have beneficial impact

$$P_{spill} = pg(h_W + h_p)q\mu_t$$



New Study

- Recapture spilled water power potential from hydro using energy storage
- Develop Controls and Applications for Energy Storage to evaluate benefits
- Develop and simulate dynamic energy storage model to determine installation location

Energy Balance Model

Objective

- Reduce diesel consumption as well as optimizing
  - Diesel generator run time
  - Diesel generator switching
  - Energy storage cycles

ESS Sizes

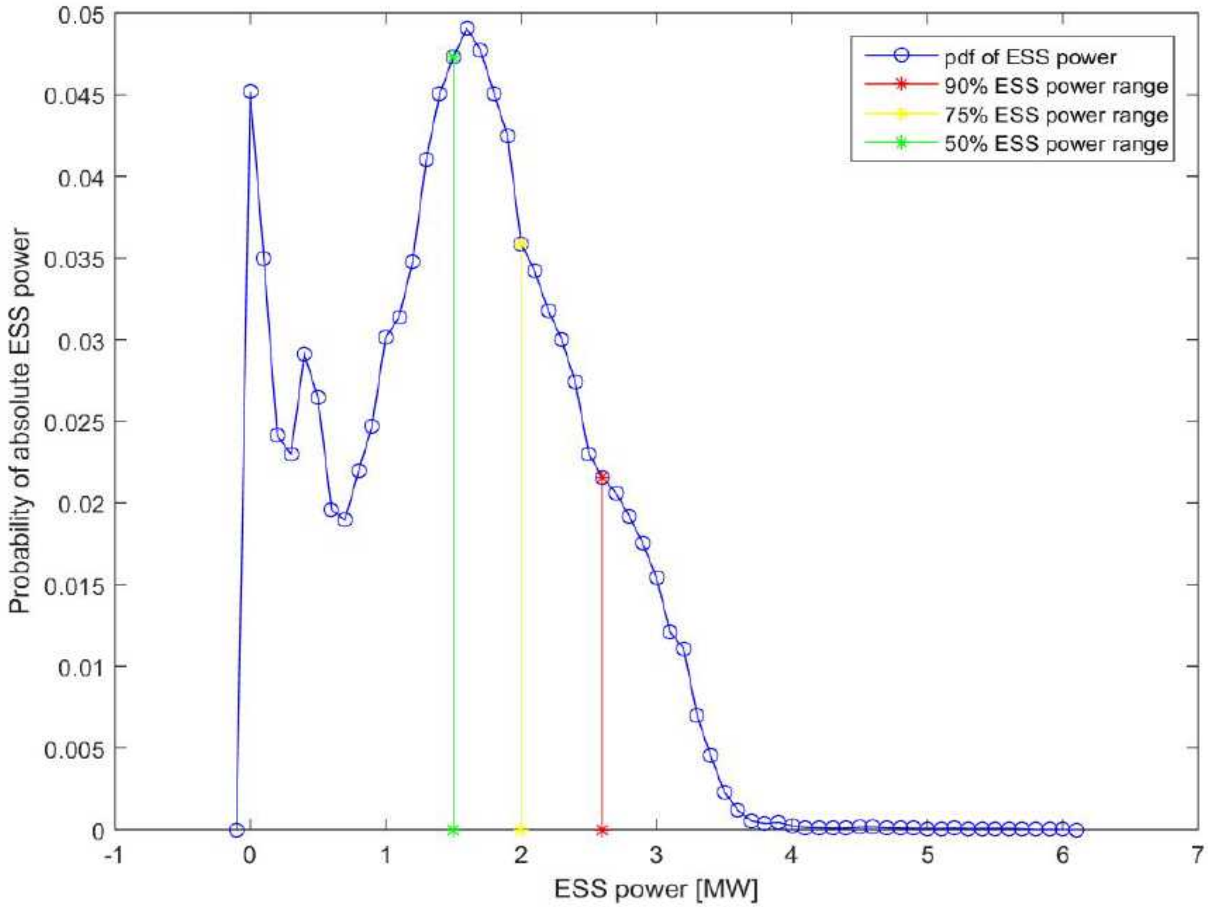
- Power (500 to 4000 kW)
- Energy (500 to 4000 kW)

Various Control Schemes used

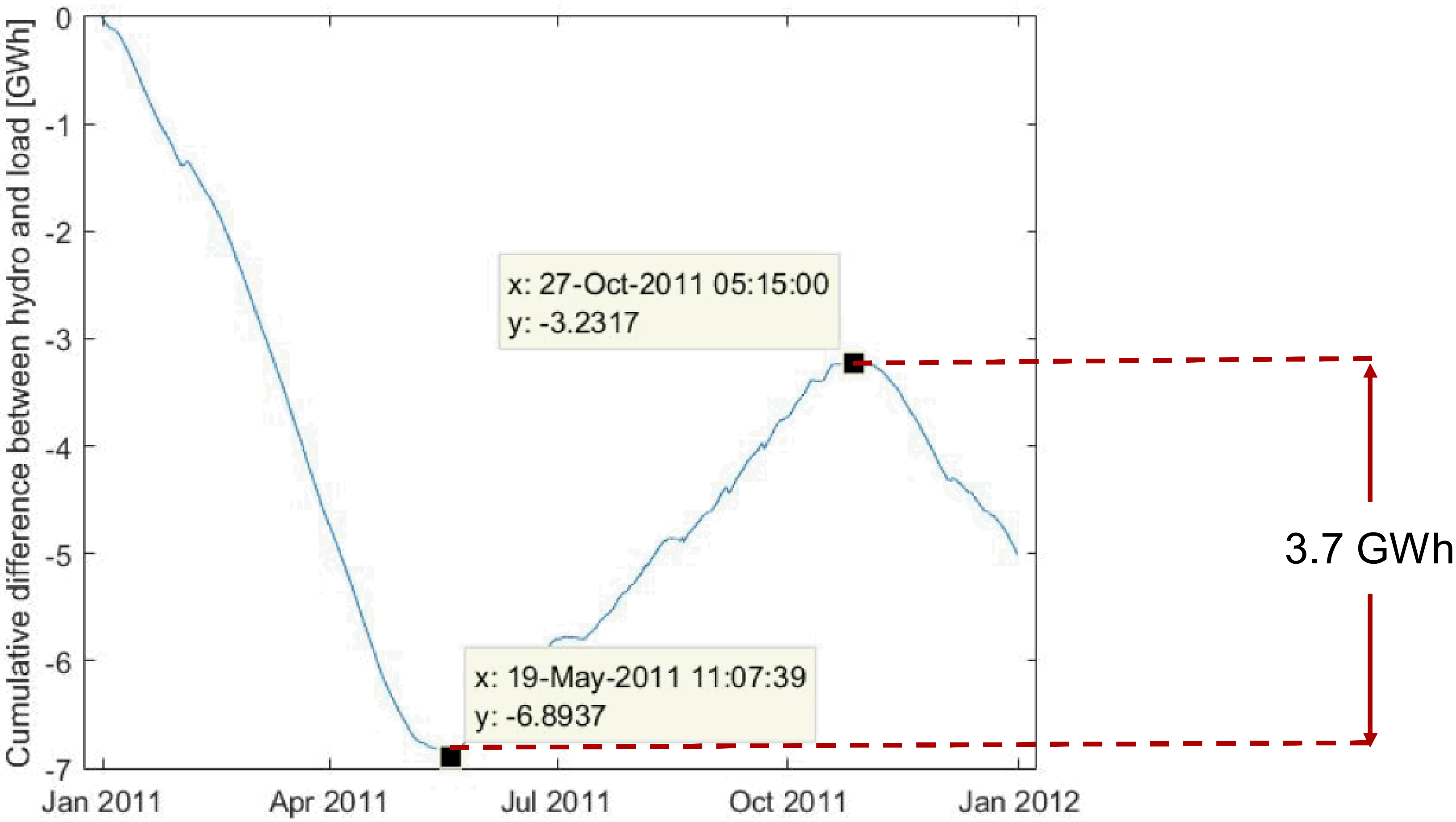
- ESS spinning reserve
- Generation dispatch modification
- Charge ESS only from diesel
- Charge ESS only from hydro
- Charge ESS from diesel and hydro
- ESS used to smooth diesel and hydro load profiles

Capture Spilled Water – ESS Size

50% of Events
1.5 MW
75% of Events
2 MW
90% of Event
2.6 MW

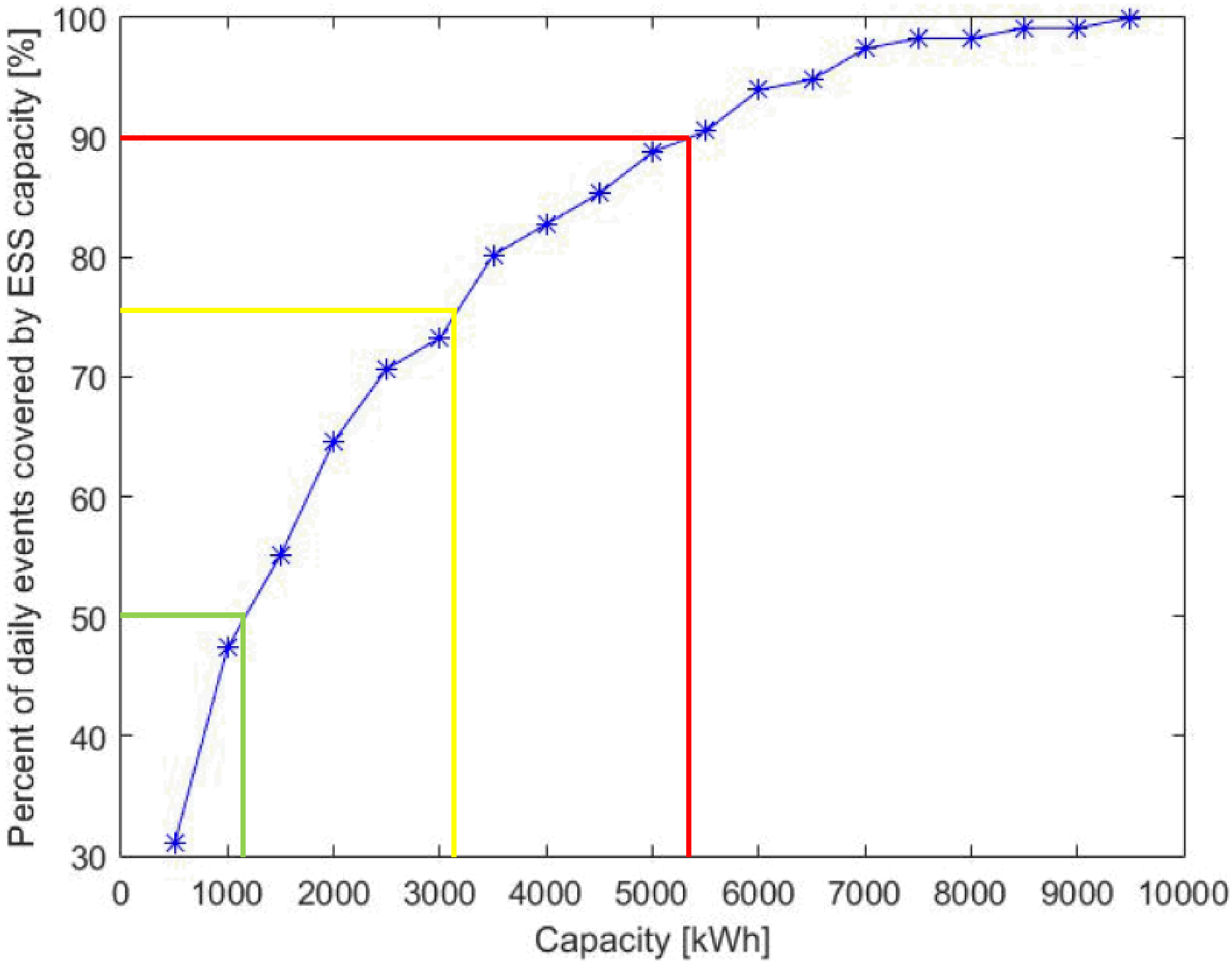


Capture Spilled Water – ESS Size



Capture Spilled Water – ESS Size

50% of Events
1.2 MWh
75% of Events
3.2 MWh
90% of Event
5.4 MWh



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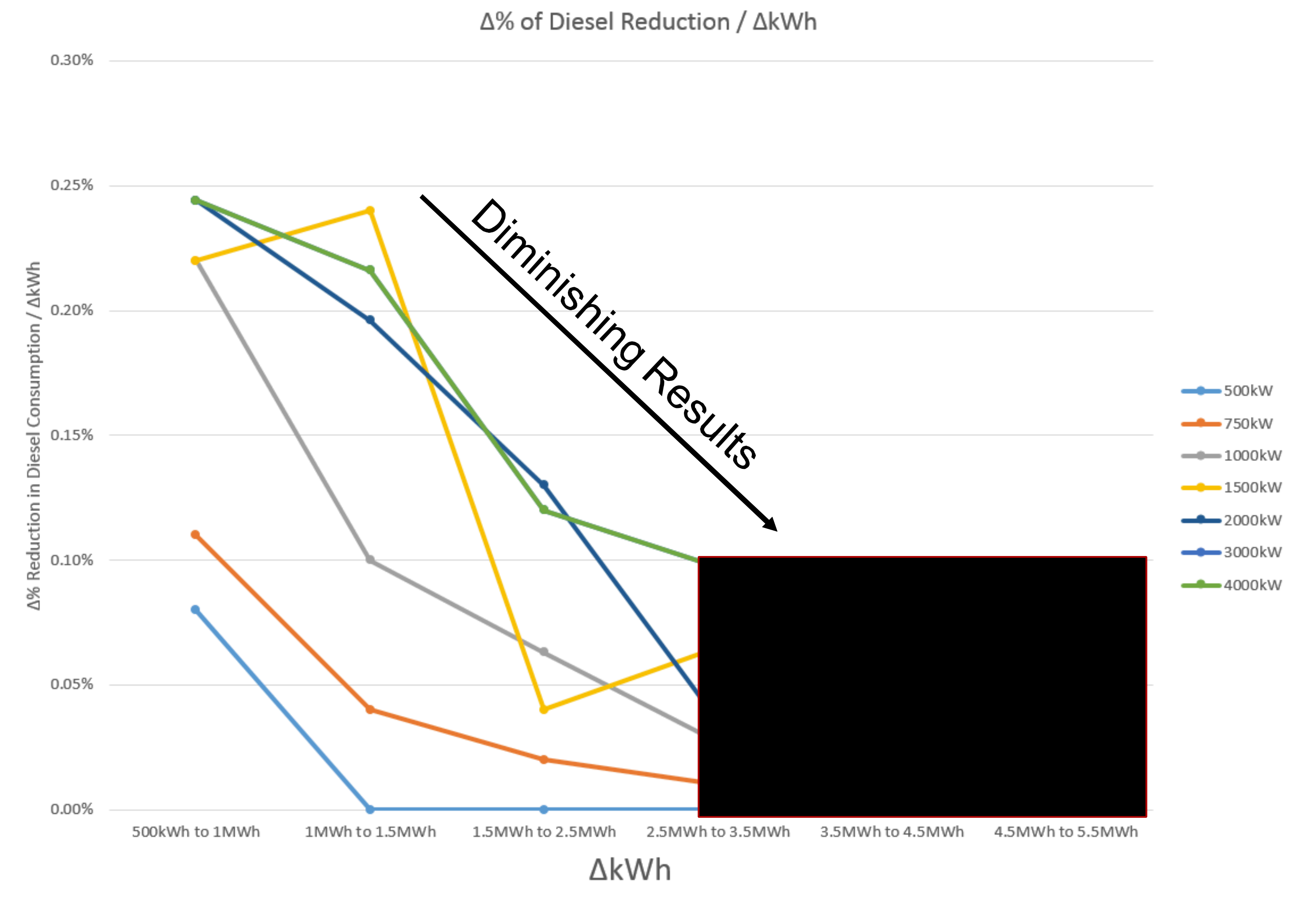
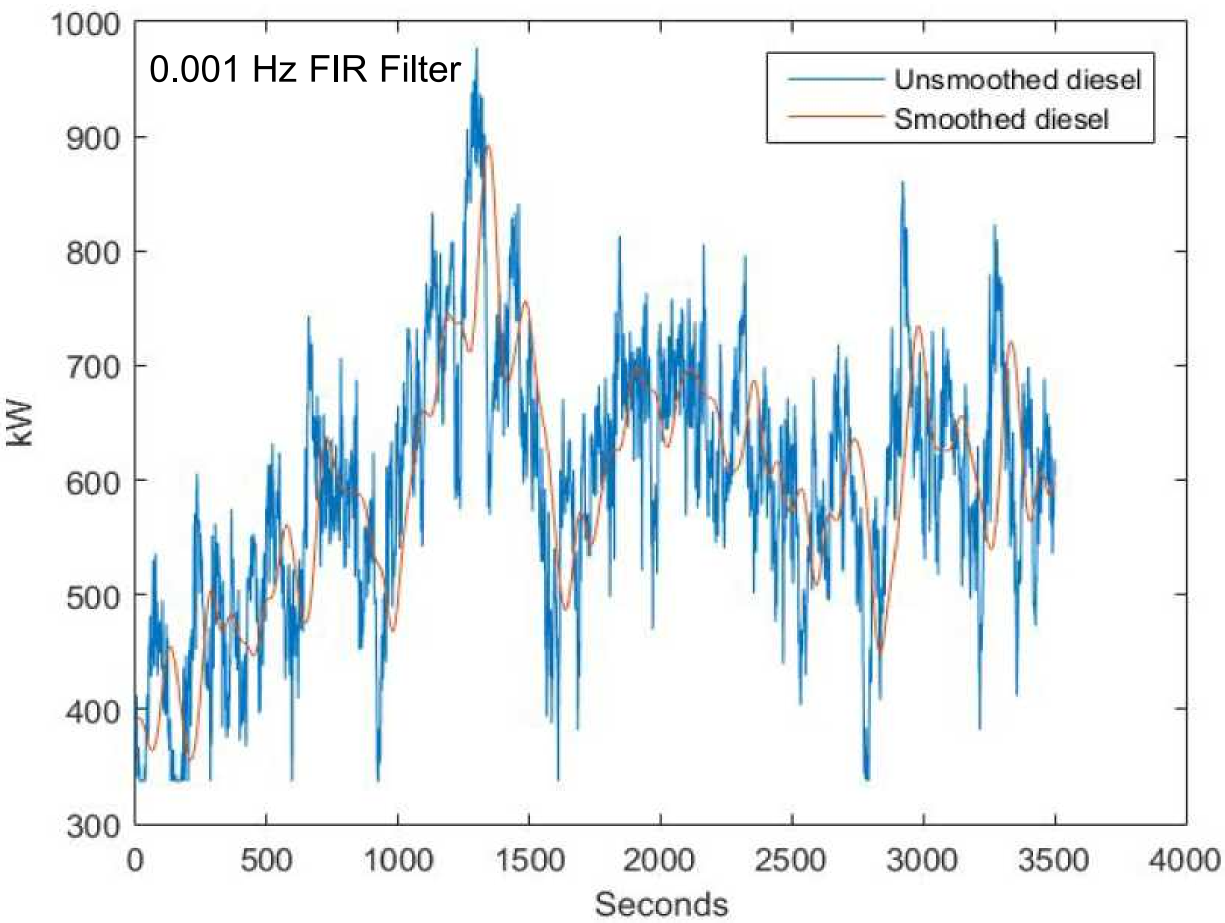
Capture Spilled Water – ESS Size



Load Smoothing and Spinning Reserve



- Reduce ramp rates on diesel and hydro units
- Reduce run time on diesel generators
- Increase diesel generator capacity factor

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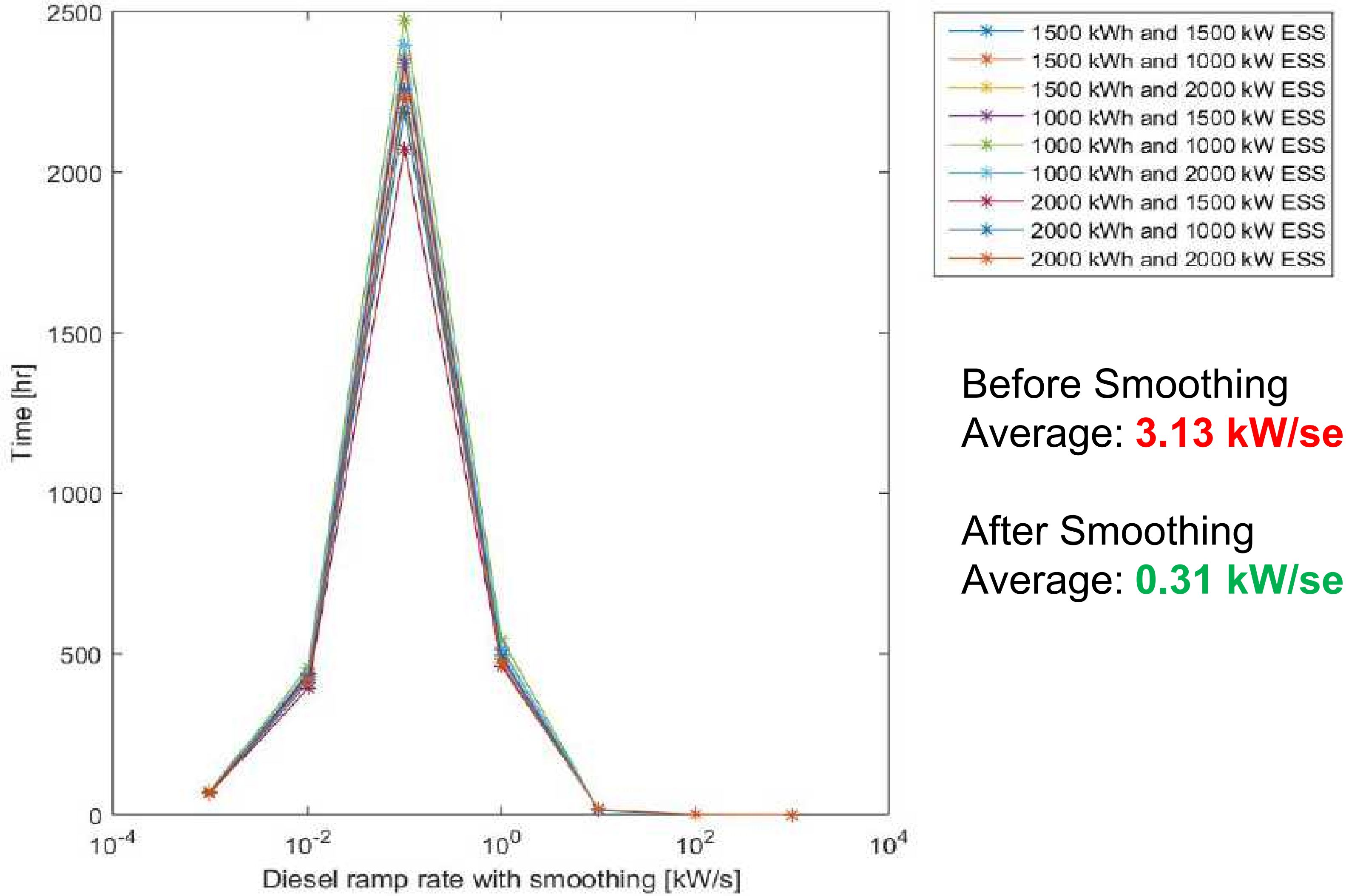
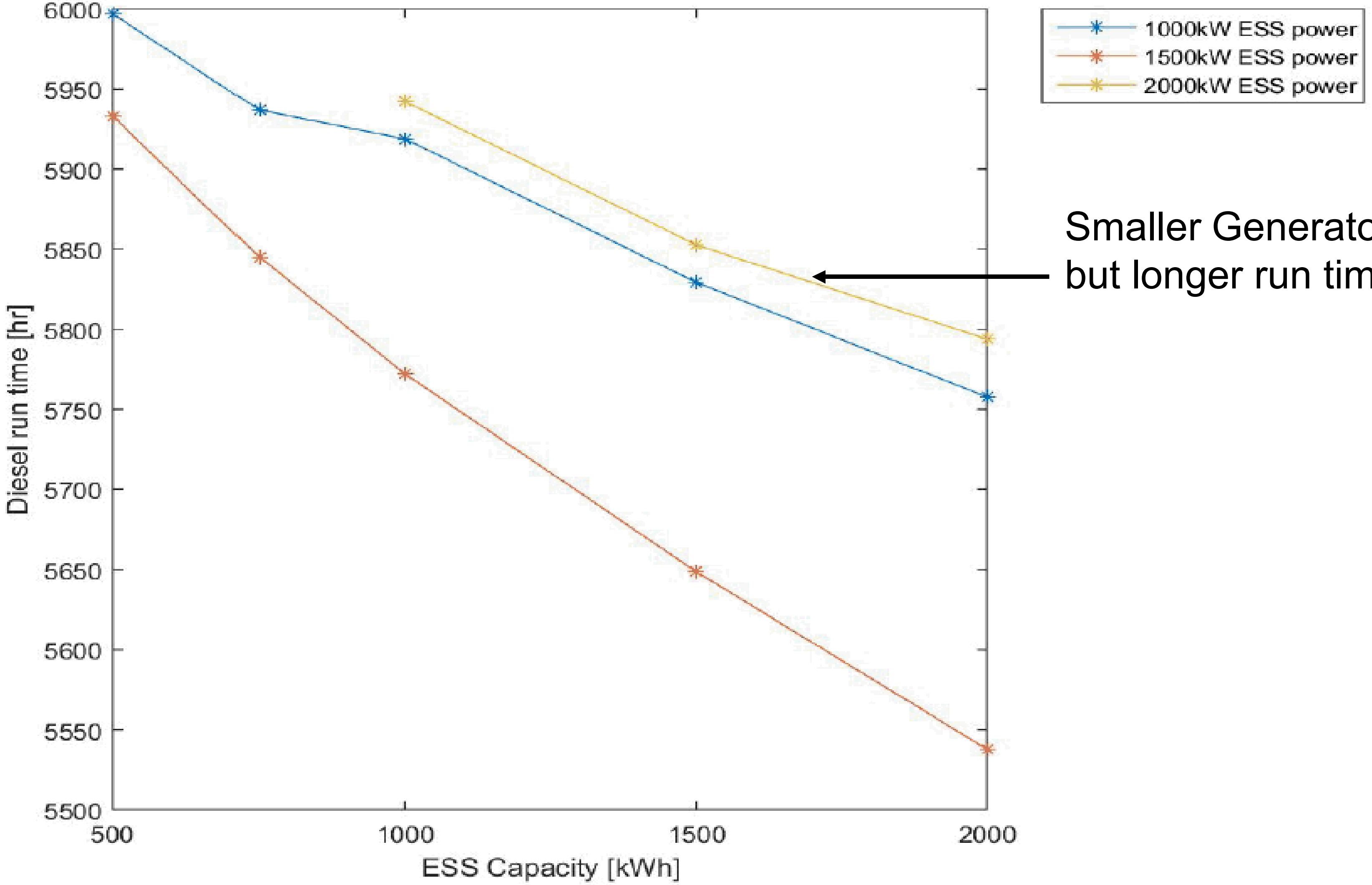
Load Smoothing and Spinning Reserve



Before Smoothing
Average: **3.13 kW/sec**

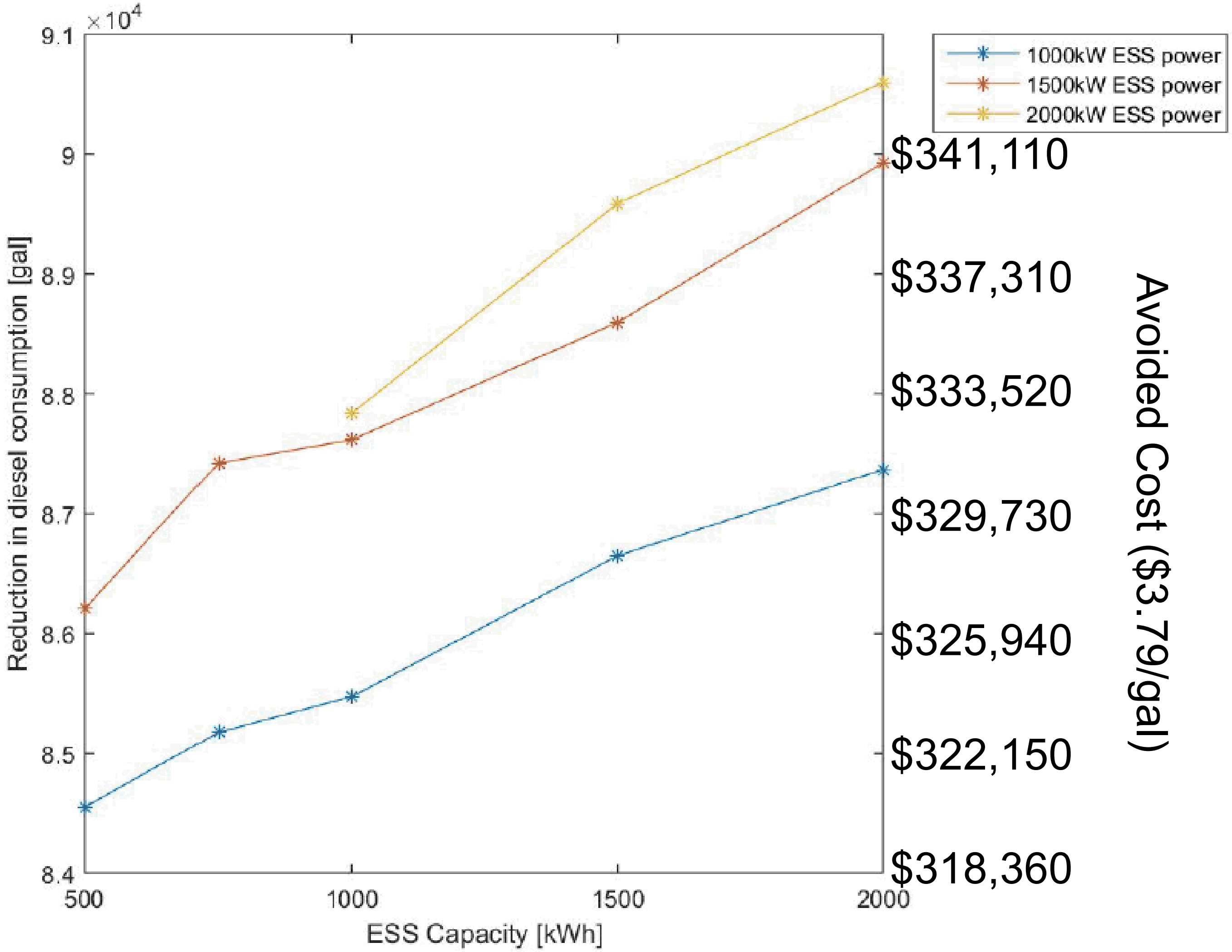
After Smoothing
Average: **0.31 kW/sec**

Load Smoothing and Spinning Reserve

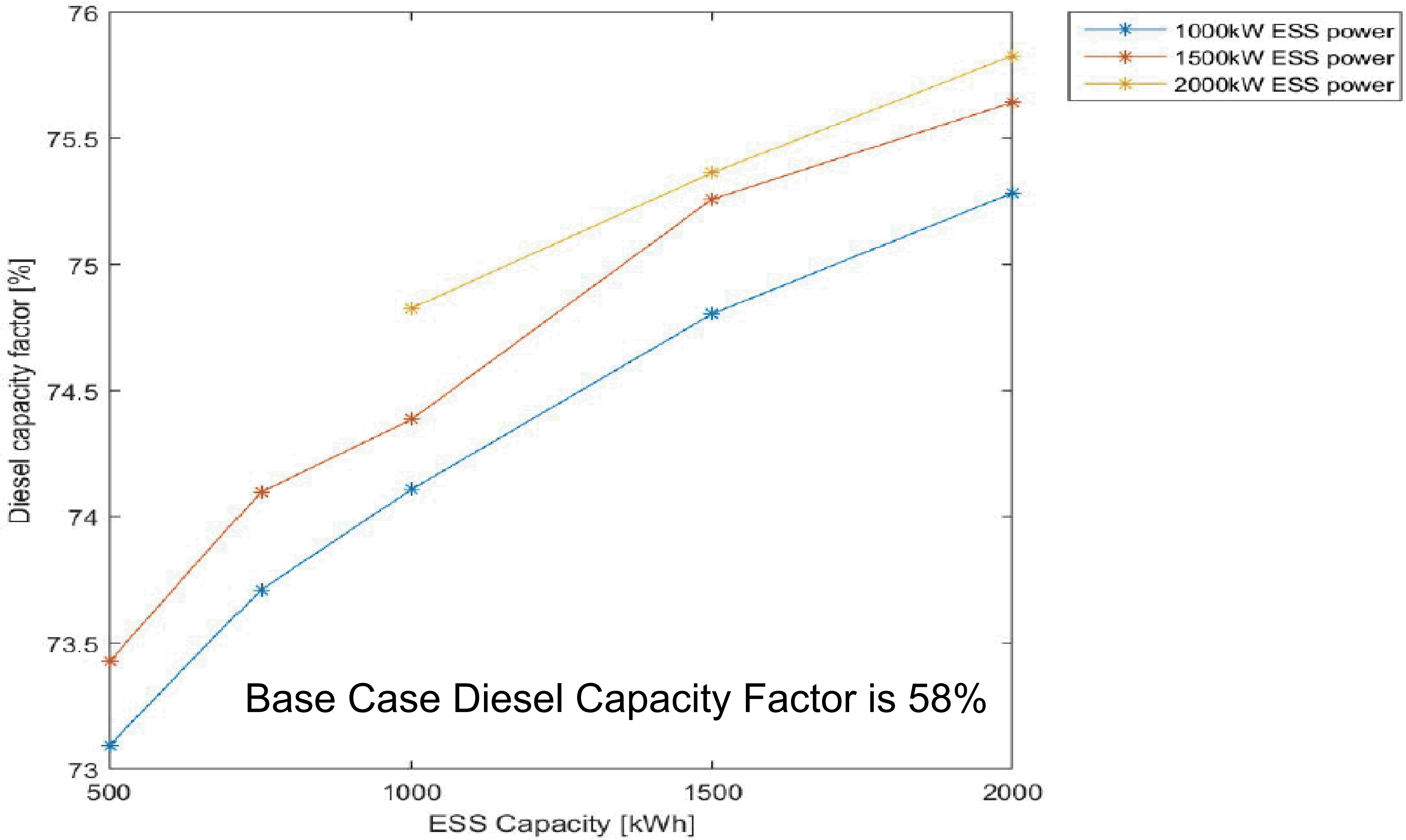


Smaller Generators but longer run times

Load Smoothing and Spinning Reserve



Load Smoothing and Spinning Reserve



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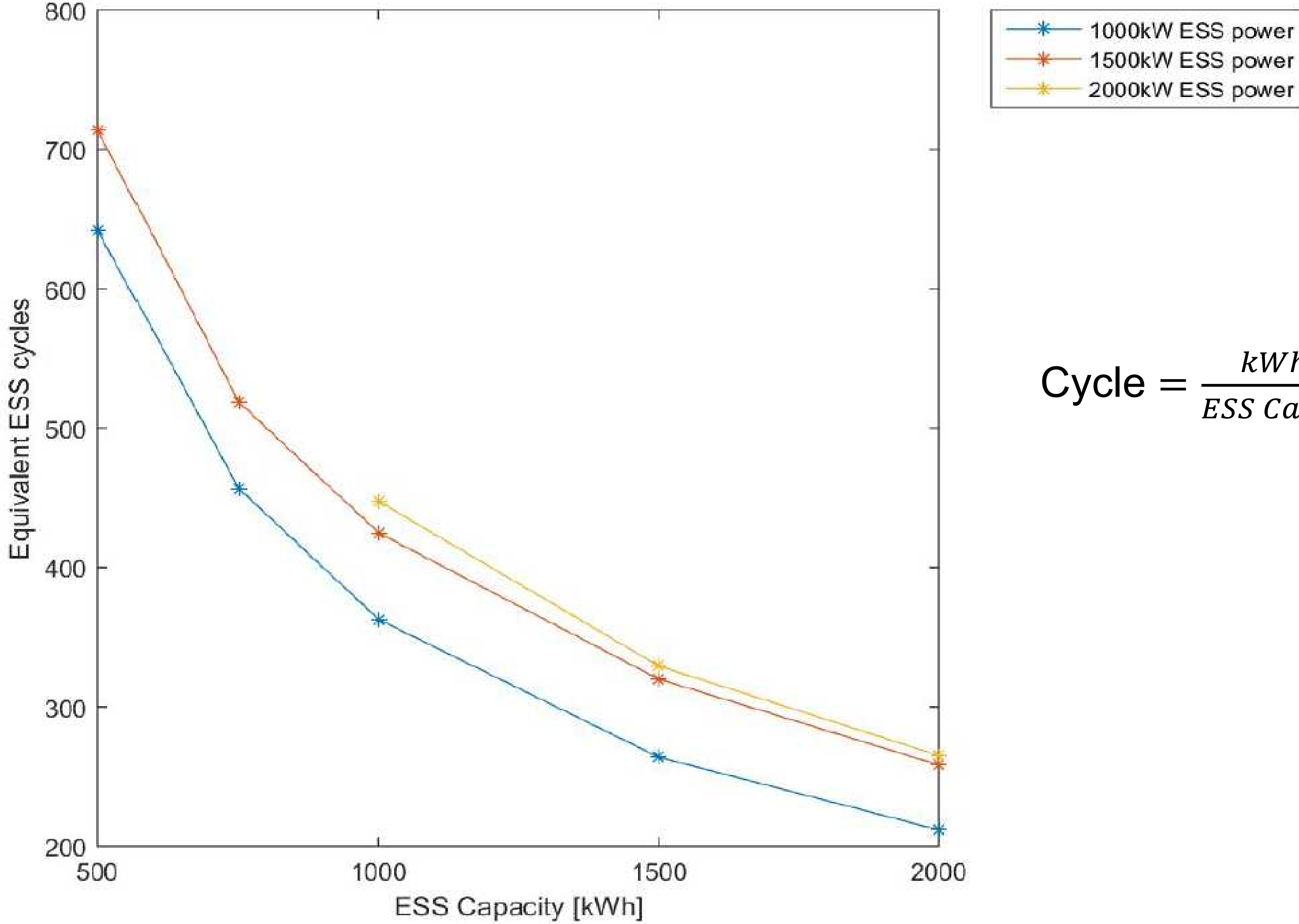
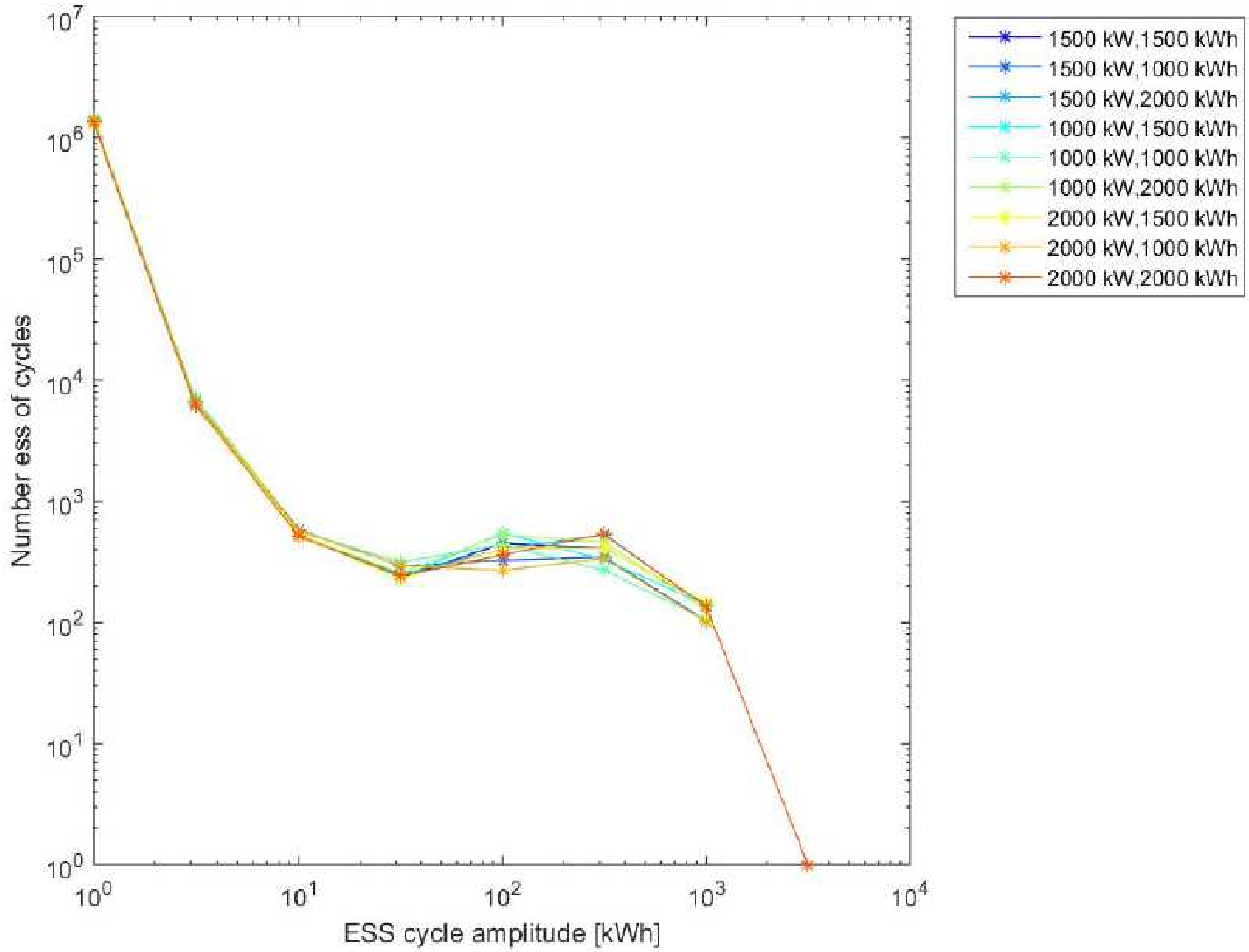
Load Smoothing and Spinning Reserve



$$\text{Cycle} = \frac{kWh\ Discharge}{ESS\ Capacity\ Rating}$$

Load Smoothing and Spinning Reserve



Simulation Comparisons (1MW/1.5MWh)

Sim Description	Base	Sim 1	Sim 2	Sim 3	Sim 4
Smoothing of Hydro and Diesel using ESS	**N/A**	**Yes**	**No**	**Yes**	**No**
MAX SOC Charging of ESS by Diesel (%)	**N/A**	**75**	**75**	**0**	**0**
Diesel Output (GWh)	10.37	9.40	9.37	9.37	9.35
Diesel Consumption (kgal)	728.17	640.55	638.75	642.98	641.44
Diesel Off Time (hr)	2816.72	4086.82	4103.13	3828.27	3841.40
Diesel Run Time (hr)	8452.11	5771.98	5796.80	6425.51	6439.73
Diesel Capacity Factor (%)	61.36	74.39	75.06	62.37	65.47
Avg. Ramp Rate (kW/sec)	3.13	0.31	3.07	0.55	3.94
ESS Cycles	N/A	424.69	301.91	251.31	99.65

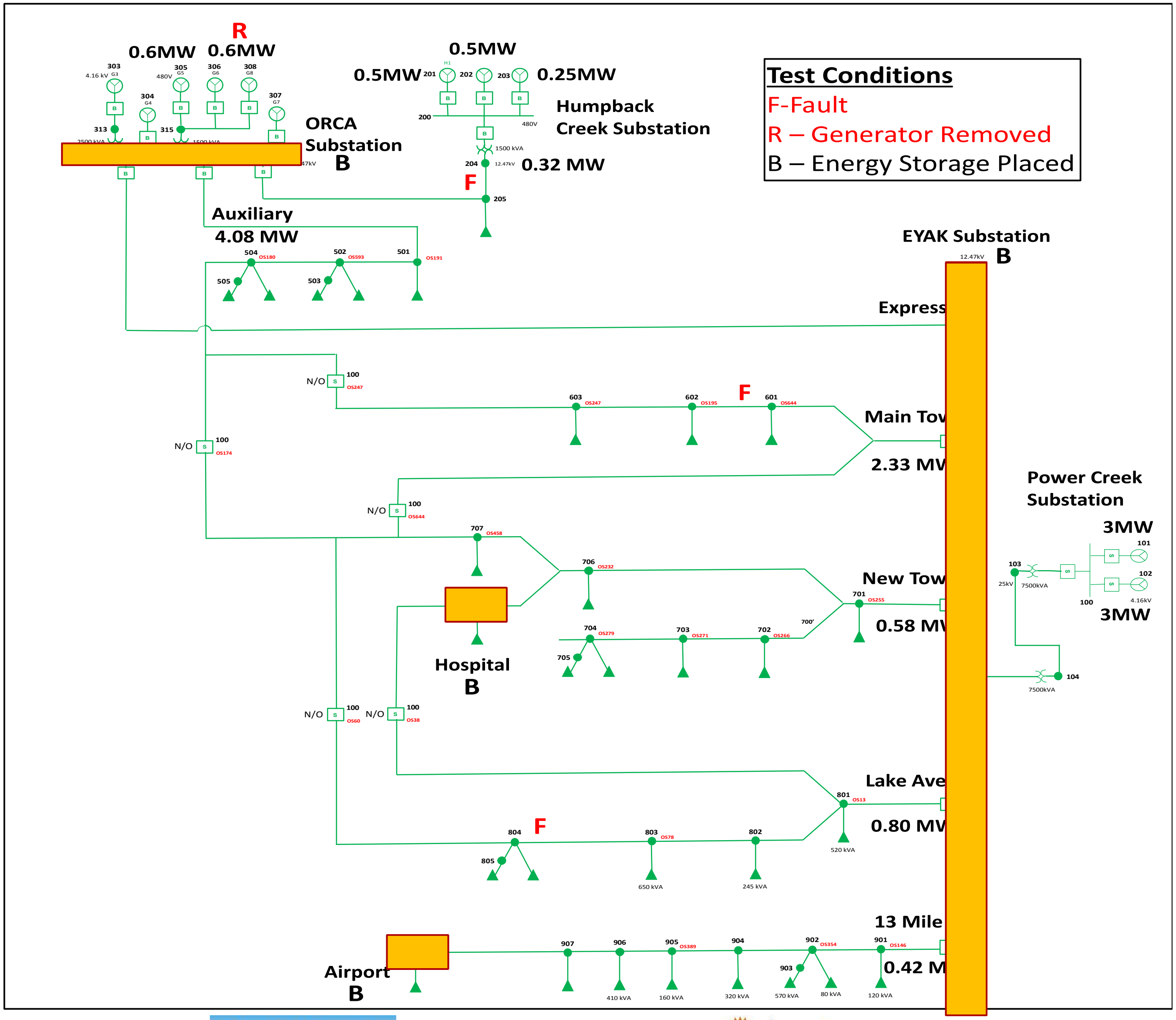
Model Summary

- Increasing ESS power and capacity had decreasing incremental benefits
- ESS sizes between 1-2 MW / 1-2 MWh were shown to be the most beneficial for CEC
- 1 MW / 1.5 MWh (No Smoothing)
  - ~86,000 gal of diesel saved (~$326,000 per year)
    http://www.alaskagasprices.com/index.aspx?fuel=D&area=Cordova&dl=Y&intro=Y
  - Reduced diesel generator runtime by 2680 hrs
  - Diesel capacity factor was increased from 66% up to 75%
  - 100-425 cycles per year
- Modifying generator dispatch control scheme to utilize more hydro
  - Saved 43,000 gal of diesel ($163,000) but
  - May not be feasible without 1 MW / 1 MWh ESS due to reliability

Dynamic Modeling

- GE Positive Sequence Load Flow (PSLF)
- Investigate system dynamics of 1 MW / 1.5 MWh ESS
  - Line Faults (100ms duration)
  - Loss of Generation (1.125MW Diesel)
- Evaluate various locations
  - Eyak Substation
  - Orca Substation
  - Hospital
  - Airport
- ESS Model
  - Frequency and Voltage Response

Dynamic Modeling



ESS LOCATIONS

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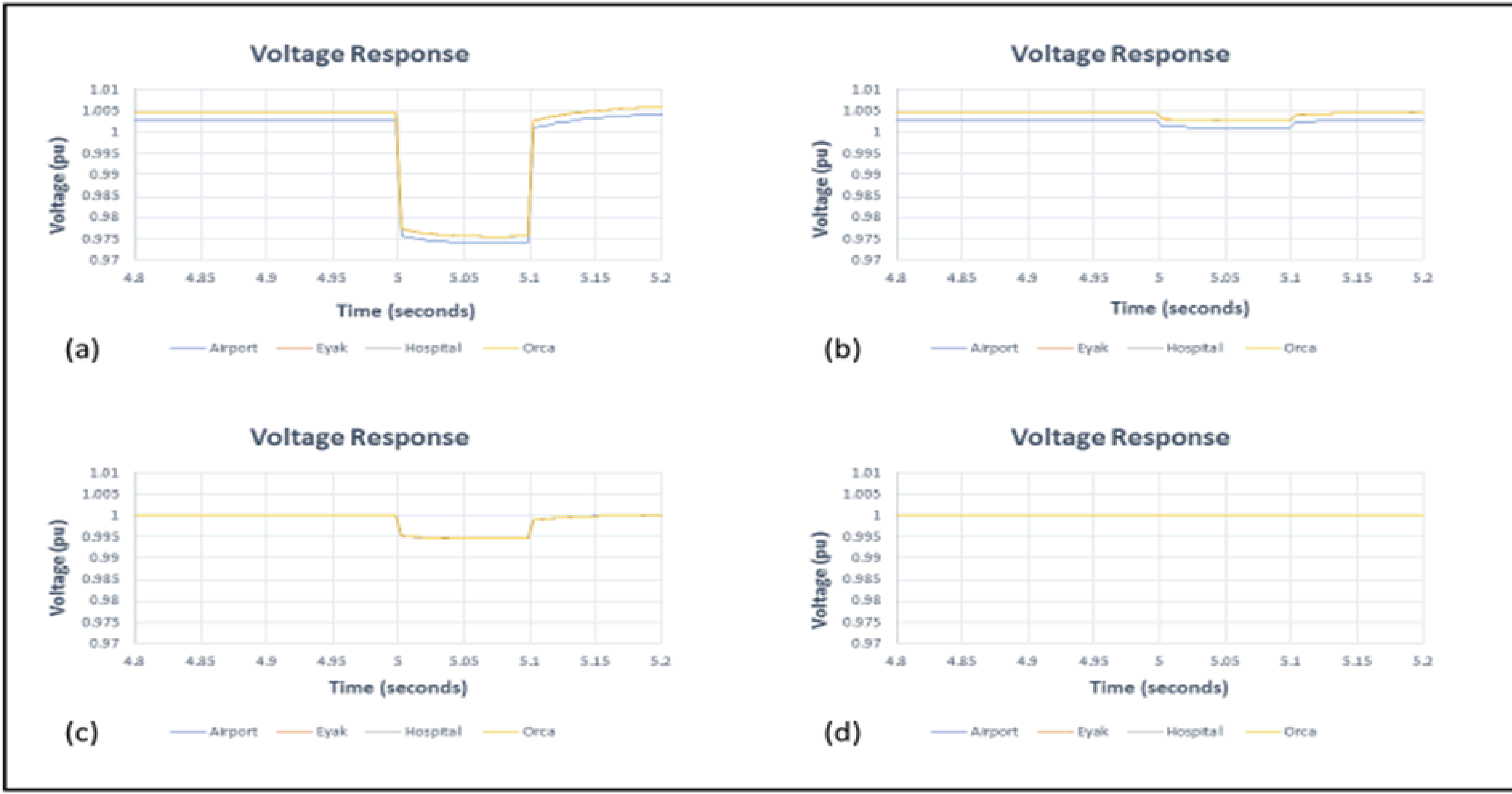
Dynamic Modeling

Humpback Creek Fault

Main Town Fault



New Town Fault

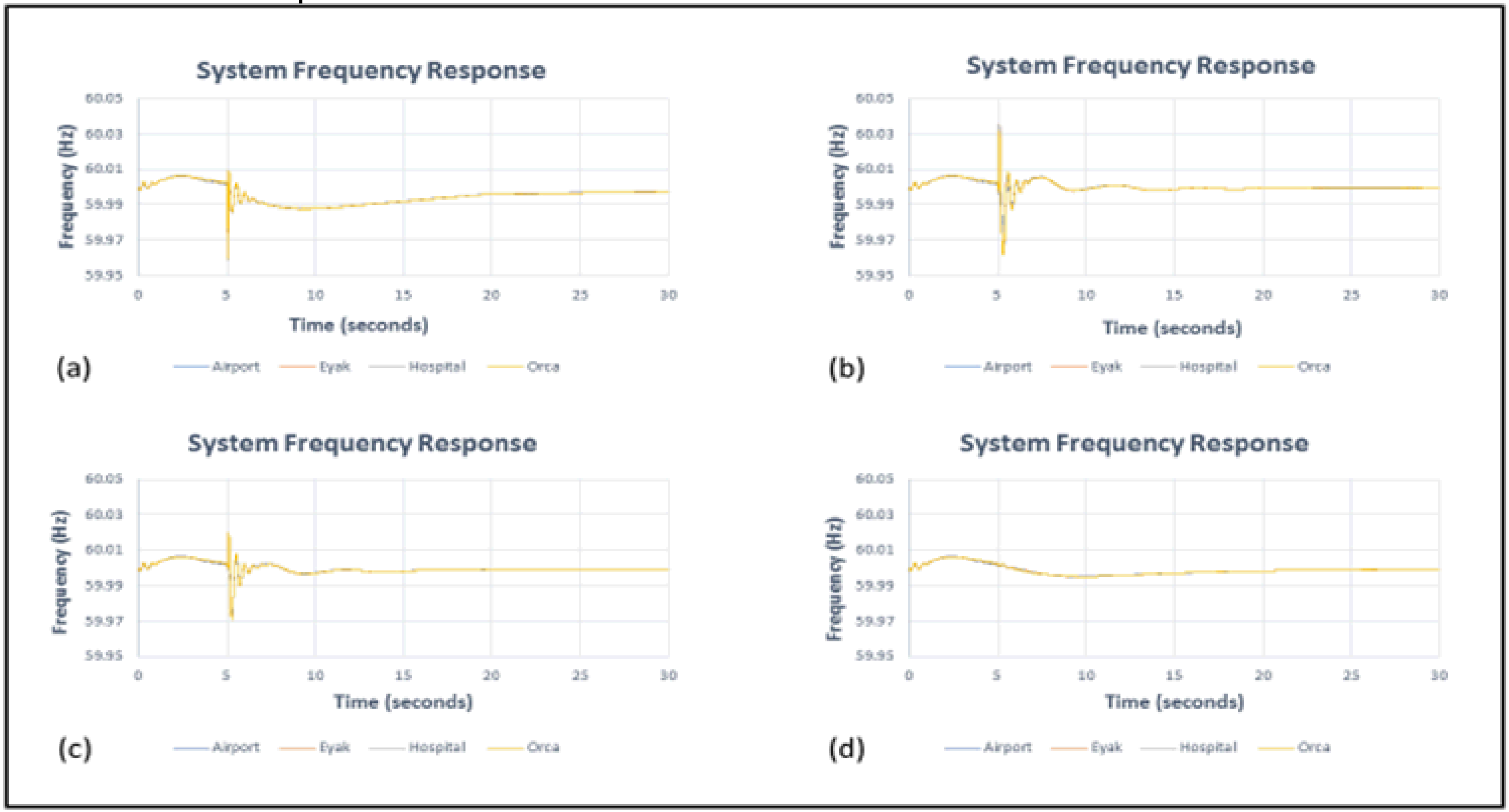
ORCA Gen Removed

Dynamic Modeling

Sandia National Laboratories

Humpback Creek Fault

Main Town Fault



New Town Fault

ORCA Gen Removed

Simulation Summary

- 1 MW / 1 MWh ESS did not have a negative dynamic affect on the Cordova System
- ESS provided some dampening during line faults and generation loss
- Placing the ESS at any of the 4 locations had very similar results
- Location of Choice for ESS is the Hospital
  - Allows Smoothing and Spinning Reserve
  - Possible UPS application (Societal Benefit)

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